Forecasting Ground-level Ozone in the Lower Fraser Valley

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Abstract
During the summer of 2002, the Pacific Weather Centre, in cooperation with the Greater Vancouver Regional District and the B.C. Ministry of Water, Land and Air Protection, issued forecasts of daily maximum 1-h ozone concentrations for 11 regions in the Lower Fraser Valley. Pacific Weather Centre meteorologists, who were provided with guidance from three statistical models, prepared the forecasts twice daily. This presentation will describe the forecasting process and the statistical models used. A verification of the forecasts showed that root mean square errors ranged from a low of less that 2.9 units of the air quality index for ozone for very short-range forecasts, to 6.1 units for forecasts with lead times of 36 hours. Biases at all lead times were small. The statistical models provided very good guidance, with most forecasts simply replicating the model output. Forecasters intervened on only 3.8% of the regional predictions—59.8% of those changes increased the accuracy of the forecast, 34.8% lessened the accuracy, and 5.4% of the changes had no effect. These results indicate that an automated ozone forecast for the Lower Fraser Valley using statistical models is feasible. Human intervention may only be required on rare occasions, most importantly when concentrations threaten to exceed the maximum acceptable federal objective.

Introduction
During the summer of 2002, the Pacific Weather Centre (PWC) of the Meteorological Service of Canada (MSC), in cooperation with the Greater Vancouver Regional District (GVRD) and the British Columbia Ministry of Water, Land and Air Protection (MWLAP), issued forecasts of daily maximum 1-hour ground level ozone concentrations for eleven regions in the Lower Fraser Valley (LFV). Forecasts were issued daily at 6 am PDT and 4 pm PDT, and covered the period from issue time to midnight of the following day. An example of the forecast bulletin is shown in Figure 1. A map of the forecast regions is shown in Figure 2.

Forecasts were disseminated on national communications circuits and posted to Environment Canada's web portal at w ww.weatheroffice.ec.gc.ca. The forecast program ran from May 1 to September 27, 2002 during which time 300 forecast bulletins were issued. This presentation describes the ozone-forecasting program for the LFV, the relationship between weather and ozone in the valley, the models used to support the forecast program, and an evaluation of the forecasts for one of the regions. The presentation concludes with a description of the work currently being undertaken to expand the air quality prediction program in the LFV.

Weather Conditions and Ozone in the LFV
Daily maximum ozone concentrations at a given location form a time series whose members are serially correlated. In the absence of other information, the best prediction for the following day's peak ozone at a location is persistence. Since weather conditions are a major determinant of ozone formation, a persistence forecast can often be improved when weather information is added. This is the role of the weather forecaster. His knowledge of local weather conditions and experience relating weather patterns to air quality conditions can be used to better simple persistence forecasts of peak ozone. Experienced forecasters know that slack surface pressure gradients, strong low-level inversions, warm air in the low levels, and strong ridges at 500 hPa, when persistent, correlate well with increasing ground level ozone concentrations in the LFV. Alternatively, precipitation events and/or inflow winds generally imply that ozone concentrations will decrease. Expert forecasters even use satellite imagery to detect future changes in ozone levels. Stratus surges along the west coast of Washington and Vancouver Island are a leading indicator for strong inflow winds through Juan de Fuca Strait and the LFV. Such inflows generally cause ozone concentrations to drop sharply within 24 hours. These events can usually be seen on satellite imagery in the visual band.

Photochemical Models
The Canadian Meteorological Centre in Montreal, Canada runs a numerical air quality model called CHRONOS (Canadian Hemispheric Regional Ozone NOx System). The model is initialized once per day at 0000 UTC and is used to support air quality forecasting within Canada. Output from this model can be obtained graphically as maps of ozone concentrations, or numerically as concentrations at various locations. A verification of the forecasts from this model will not be presented here. Forecasters at the PWC have generally found this guidance to be marginally useful for determining patterns and trends in ozone concentrations over BC, but generally inadequate to the task of predicting numerical values

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FLCN40 CWVR 121200
GROUND LEVEL OZONE FORECAST FOR SELECTED REGIONS OF BRITISH COLUMBIA
ISSUED AT 6 AM PDT FRIDAY 12 JULY 2002 FOR TODAY AND SATURDAY.
FORECAST ISSUED JOINTLY BY THE PACIFIC WEATHER CENTRE OF ENVIRONMENT
CANADA AND THE GREATER VANCOUVER REGIONAL DISTRICT AND THE B.C.
MINISTRY OF WATER LANDS AND AIR PROTECTION. THE NEXT SCHEDULED
FORECAST WILL BE ISSUED AT 4 PM TODAY.

GREATER VANCOUVER.
                           TODAY        SATURDAY
                           AQI/CATEGORY AQI/CATEGORY
VANCOUVER..................21/GOOD      17/GOOD
NORTH SHORE................21/GOOD      19/GOOD
RICHMOND/DELTA.............18/GOOD      18/GOOD
BURNABY/NEW WESTMINSTER....19/GOOD      19/GOOD
NORTHEAST..................18/GOOD      19/GOOD
SURREY/NORTH DELTA.........24/GOOD      20/GOOD
RIDGE MEADOWS..............31/FAIR      25/GOOD
LANGLEY....................27/FAIR      22/GOOD

LOWER FRASER VALLEY.
                           TODAY        SATURDAY
                           AQI/CATEGORY AQI/CATEGORY
ABBOTSFORD.................25/GOOD      23/GOOD
CHILLIWACK.................28/FAIR      21/GOOD
HOPE.......................38/FAIR      26/FAIR

B.C. INTERIOR.
                           TODAY        SATURDAY
                           AQI/CATEGORY AQI/CATEGORY
KAMLOOPS...................32/FAIR      31/FAIR
KELOWNA....................35/FAIR      35/FAIR

AIR QUALITY CATEGORIES OF 'GOOD', 'FAIR', 'POOR' CORRESPOND
TO AIR QUALITY SUB-INDEX RANGES OF 0-25, 26-50 AND >50 RESPECTIVELY.

"ADVERSE HEALTH EFFECTS INCREASE AS AIR QUALITY DETERIORATES."

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END/RN
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Figure 1. Example of 6 am forecast bulletin.

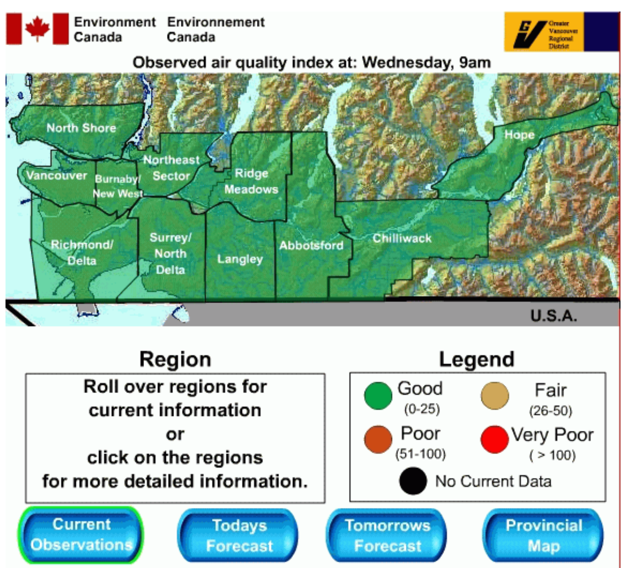

Figure 2. Lower Fraser Valley regions.

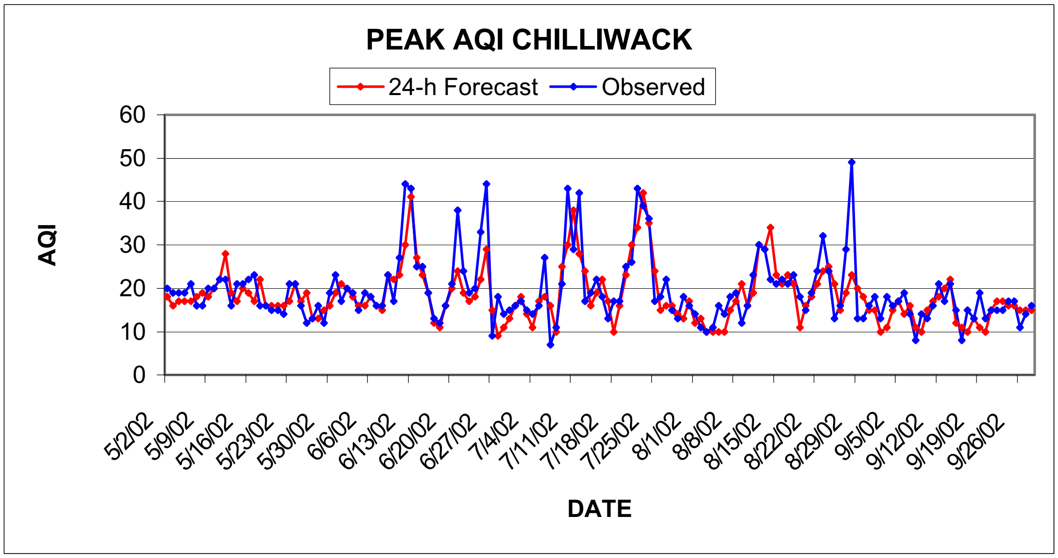

Figure 3. Time series of the 24-h ground level ozone forecasts for Chilliwack (in red) and the verifying observations (in blue).

of peak ozone. The model has a bias to under predict peak ozone in the LFV and exhibits large mean squared errors at specific points. The consensus among PWC forecasters is that CHRONOS in its present form has the utility of numerical weather prediction models of the late 1970s.

Empirical models

Three statistical models were developed to support the forecast program: a lognormal regression model and two artificial neural network ensemble models. Models of each type were developed to predict peak ozone at 18 monitoring stations in the LFV as well as to independently predict peak ozone in the LFV as a whole.

Each model used seven predictors: the previous day's peak ozone concentration at the station, the forecast maximum temperature at either Vancouver airport (YVR) or Abbotsford airport (YXX), the forecast occurrence of precipitation at either YVR or YXX, the forecast pressure gradient across the LFV (inflow or outflow), the forecast temperature at 850 hPa at either YVR or YXX, and two functions of the day of the year describing seasonal development. Details of the models can be found in Lord (2002a). The neural network ensemble models were trained using cases selected from 6 years of ozone observations (1995 to 2000). During training, members of the first ensemble were presented cases reflecting a distribution of ozone observations normally found during summer in the LFV. Members of the second ensemble were trained using cases specially selected to reflect an equal number of good, fair and poor ozone days (Cannon and Lord 2000), making the second model more sensitive to extreme values of peak ozone.

Verification of Forecasts

A complete performance evaluation of the 2002 ground level ozone forecasts can be found in Lord (2002b). An illustration of forecast performance is shown in Figure 3 which shows a time series of the 24-h forecasts for Chilliwack and the verifying observations, and Figure 4 which shows a scattergram of the two series.

The root mean square error for the forecasts shown in these figures is 5.1 AQI units, the bias is –1.1 AQI units, and the skill with respect to a simple persistence forecast is 36%. Over all regions, root mean square errors range from 2.9 AQI units for very short-range forecasts to 6.1 AQI units for forecasts with lead times of 36 hours. Biases at all lead times are small. The skill with respect to persistence ranges from 57% for the short-range forecasts down to 6% for the forecasts with longer projections. All forecasts are more accurate than persistence.

Forecasters appeared well served by the empirical models that guided them. In fact, 96% of the forecasts generated by these models were accepted without change by the forecasters. Of the 4% of forecasts that were changed, 60% of the changes decreased the absolute error of the forecast, 35% increased the absolute error, and 5% left the absolute error unchanged. Figure 4 shows that forecast error tends to increase as observed AQI due to ozone increases above 25. Fortunately, most summer days in the LFV have good air quality so the empirical models handle the majority of days very well. Forecasters are encouraged to use their knowledge and experience to adjust model output on those days when ozone levels are expected to rise into the fair and poor categories.

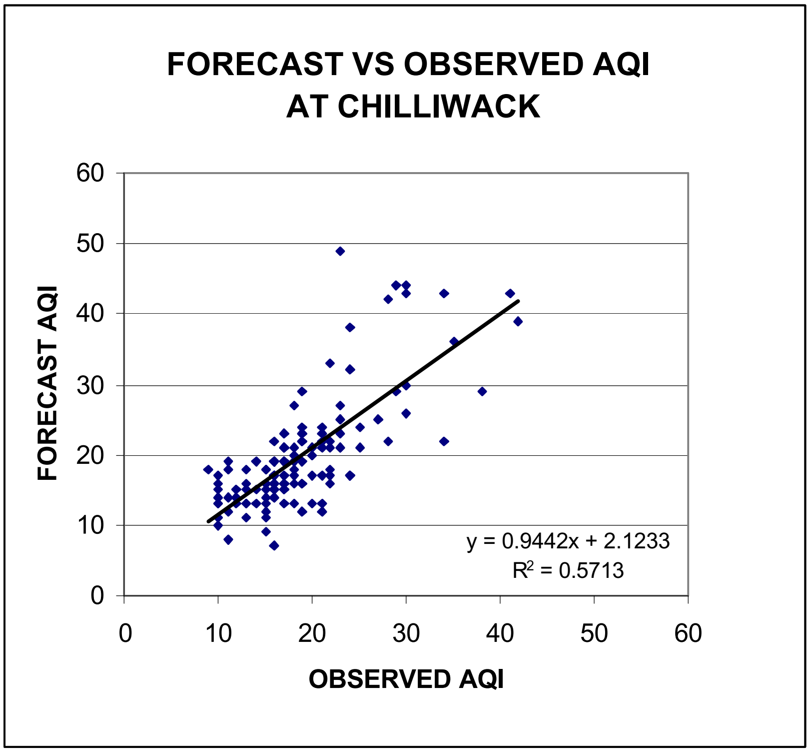

Figure 4. Scattergram of data in Figure 3 with least squares linear regression line superimposed.

Future Work

The summer time ground level ozone forecasting program for the LFV will be expanded in 2003 to include predictions of daily maximum 24-hour average PM10 concentrations. Empirical models that use ensembles of neural networks will support these forecasts. In future years it is hoped that similar models will be developed for other pollutants.

Acknowledgement

I would like to thank the Monitoring and Assessment Division of the GVRD Air Quality Department for providing real-time observations of ozone from their monitoring network.

References

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